AD NUMBER
AD099264

CLASSIFICATION CHANGES

TO: unclassified

FROM: confidential

LIMITATION CHANGES

TO:
Approved for public release, distribution unlimited

FROM:

AUTHORITY

NRL ltr. 7103/113, 23 Oct 96; NRL lte. 7103/113, 23 Oct 96

CONFIDENTIAL

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NRL Report 4726
Copy No.

SIMULATION OF SONAR TRACKING

[CONFIDENTIAL TITLE]

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FC

May 22, 1956

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ABSTRACT
[Confidential]

Equipment has been developed which generates range and bearing data comparable to that obtained from maneuverable own ship and target ship. This continuous information is converted, through circuits simulating the information-handling circuits of the SQS-4 Sonar, to the intermittent data flow which exists between the SQS-4 Sonar and the Mark 5 Attack Director. This equipment has been connected to a Mark 5 Attack Director and has been used to simulate operation of a Mark 105 Fire Control System.

PROBLEM STATUS

This is an interim report on one phase of the problem; work on other phases is continuing.

AUTHORIZATION

NRL Problem No. S05-13
Bureau Problem No. C 4b-94

Manuscript submitted March 21, 1956

SIMULATION OF SONAR TRACKING
[Confidential Title]

INTRODUCTION

The increased complexity of sonar-fire-control systems has created a need for methods of determining the compatability of equipment under development. Ultimate shipboard evaluation is required in order to establish the merit of these new systems. Fleet exercises, however, are costly and time consuming; involve extensive preparation and planning; and require the use of scarce submarine time. In addition, difficulty is experienced in obtaining data which is free of such undesired factors as operator error, variability of sonar conditions, uncertainty in target location, and dependency on reconstruction for the evaluation of weapon miss distance. Much information concerning the compatability of equipments can be obtained prior to shipboard installation from laboratory studies, which use inputs generated from known speeds and courses and are not dependent on a human operator for sonar tracking. A portion of this equipment would be a computer to generate range and bearing of the target from own ship; the remainder would present to the fire-control equipment the target range and bearing modified to include the delays inherent in the sonar equipment. The total equipment would be a simulation of the sonar equipment with maneuverable target and own ship to provide signals to fire-control equipment.

Simulation equipment, shown in Fig. 1, which will achieve the desired performance, has been developed to investigate SQS-4 Sonar and Attack Director, Mark 5, operation. This report describes the Relative Motion Computer and the Sonar Simulator.

LIST OF SYMBOLS

S_t	Target Speed
S_o	Own Ship Speed
C_t	Target Course
C_o	Own Ship Course
Bq	True Bearing From Own Ship to Target
Brq	Relative Bearing From Own Ship to Target
Rq	Range from Own Ship to Target
A	Target Aspect; angle measured clockwise from target course to line of sound
ΔcRq	Rate Aided Tracking: Range
ΔcBq	Rate Aided Tracking: True Bearing

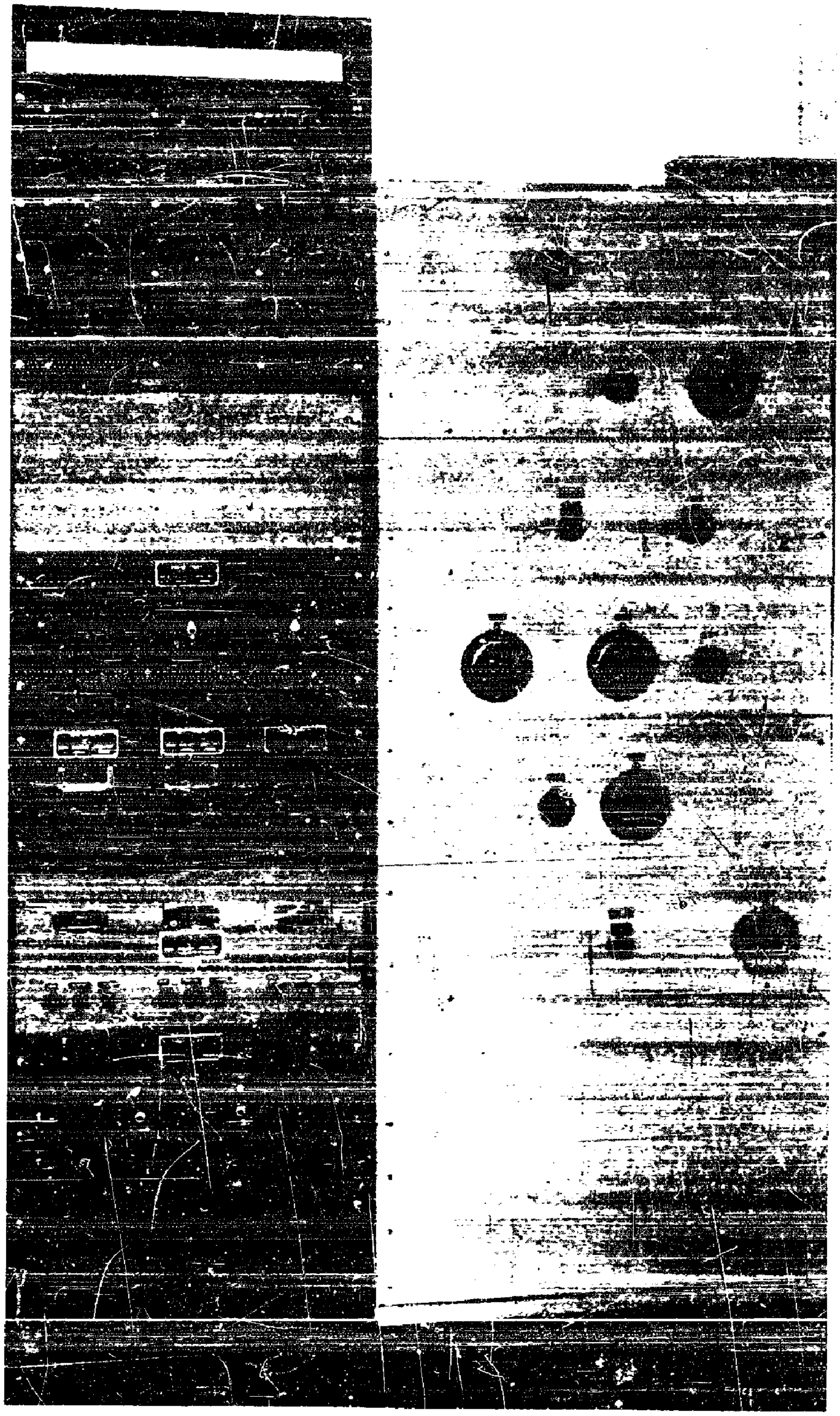

Fig. 1 - Sonar simulation equipment

jRq	Correction to Range
jBq	Correction to True Bearing
▷	Amplifier
(M)	Servomotor
(G)	Tachometer Generator
(SG)	Synchro Generator
(CT)	Synchro Control Transformer
(DG)	Synchro Differential Generator
$\boxed{\text{SIN}}$	Sine-Cosine Mechanism
$\boxed{\text{INT}}$	Ball-Disc Integrator
$\boxed{\text{RES}}$	Resolver
	Mechanical Differential
	Manual Input Knob
$\boxed{\text{POT}}$	Potentiometer
(+)	Summing Point

THEORY AND GENERAL DISCUSSION

Relative Motion Computer

The Relative Motion Computer is an analog computer designed to receive inputs of target course and speed together with own ship course and speed, and to compute outputs of range and bearing of target from own ship. All computations are made on the basis of fixed courses and speeds; however, the Relative Motion Computer can, at any time, accept a change in course or speed and compute on the basis of the new information.

Figure 2 is a plot of a typical problem. (A list of terms and symbols is given to aid in interpretation of diagrams and equations.) Inspection of the angular relations at own ship and target on Fig. 2 discloses these equations:

$$Brq = Bq - C_o \tag{1}$$

$$A = -180° + Bq - C_t . \tag{2}$$

When the ships are proceeding on constant courses at fixed speeds, differentiating Eq. (1) and (2) with respect to time gives a third equation

$$\frac{d\ Bq}{dt} = \frac{d\ A}{dt} = \frac{d\ Bq}{dt} . \tag{3}$$

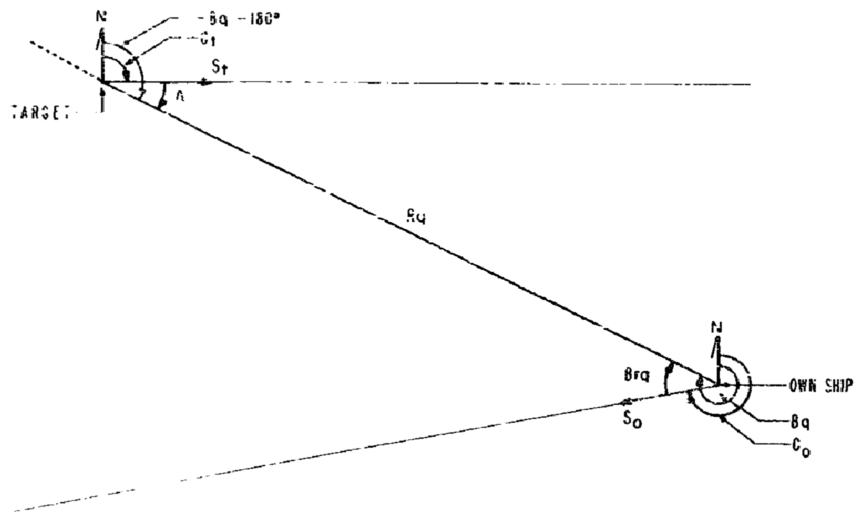

Fig. 2 - Geometry of relative ship motion

Subtracting Eq. (2) from Eq. (1) leads to

$$Brq - A = \text{constant}. \tag{4}$$

The relation for rate of change of range may be developed by consideration of relative ship motion along the line of sound

$$\frac{d\,Rq}{dt} = S_o \cos Brq + S_t \cos A. \tag{5}$$

Development of the equation for rate of change of bearing is perhaps best undertaken by considering first one and then the other ship to be stationary, and then combining the resulting relations through use of superposition theory. If own ship is stationary, the motion of the target across the line of sound could be expressed by

$$Rq\frac{\Delta\,Bq}{\Delta t} = -S_t \sin A. \tag{6a}$$

The term $Rq\frac{\Delta Bq}{\Delta t}$ is the familiar $R\theta$ relation for an arc of a circle and $S_t \sin A$ is the chord of that arc; therefore, to preserve accuracy Δt is allowed to approach zero and the equation becomes

$$Rq\frac{d\,Bq}{dt} = -S_t \sin A. \tag{6b}$$

For a stationary target the relation for motion due to own ship, derived in parallel fashion, becomes

$$Rq\frac{d\,Bq}{dt} = S_o \sin Brq. \tag{6c}$$

Combining (6b) and (6c) gives the complete relation for rate of change of bearing

$$\frac{d\,Bq}{dt} = \frac{S_o}{Rq}\sin Brq - \frac{S_t}{Rq}\sin A. \tag{6}$$

A block diagram of a computer which utilizes the relationships defined in Eqs. (1), (2), (5), and (6) to give own ship and target motion is presented in Fig. 3. Description of the relative motion computer can best begin by describing the range-computing section

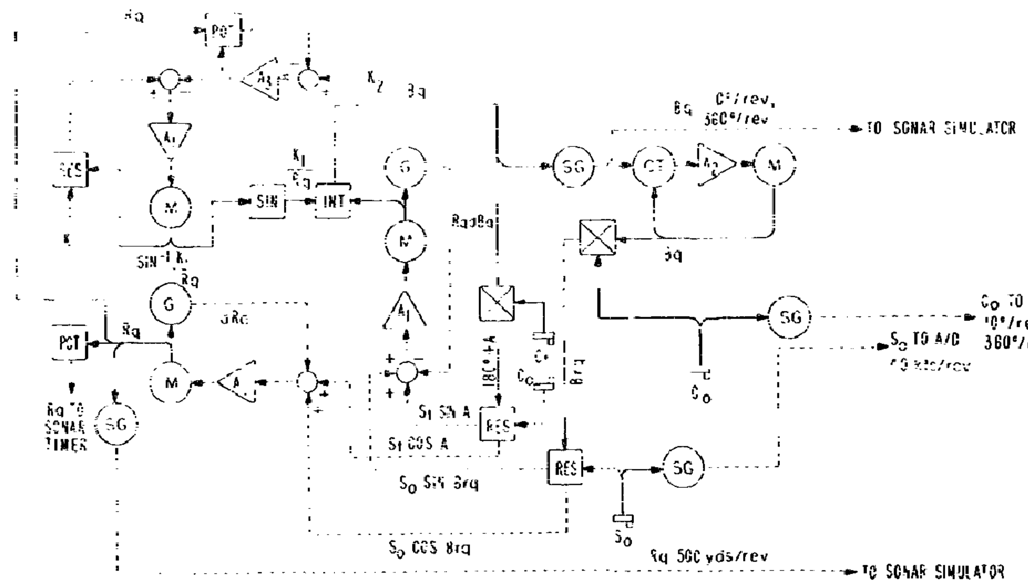

Fig. 3 - Relative motion computer

diagrammed in Fig. 4. This section receives bearing, Bq, from the bearing computing section, Fig. 5, and applies it to the inputs of two mechanical differentials. One of the differentials subtracts C_o from Bq to obtain Brq, while the other differential subtracts C_t from Bq to obain $180^0 + A$. These shaft angular positions are respectively the mechanical inputs to two resolvers. The electrical inputs to the two resolvers are voltages proportional to S_o and S_t. A resolver is a synchro-type component which gives electrical outputs equal to the product of its electrical input times the sine or cosine of its mechanical input. The range servo utilizes the cosine outputs; therefore, the two resolver output signals are electrical voltages proportional to $S_t \cos A$ and $S_o \cos Brq$. The cosine of $180^0 + A$ is equal to $-\cos A$; therefore, the cosine winding of the target-ship resolver is reversed to give a positive output of $S_t \cos A$.

The two resolver signals are added, as shown in Fig. 4, together with the tachometer-generator output signal, and the resultant signal is applied to the servo motor after amplification. The servo motor will drive the tachometer generator in a direction and at speed such as to tend to make the generator voltage equal to the sum of the two resolver signals. The tachometer-generator voltage is opposite in sign from the sum of the two resolver signals; therefore, the input voltage approaches zero. If the amplifier gain could be made infinite, the input voltage would be reduced to zero, and the tachometer-generator voltage would be exactly equal to the sum of the two resolver signals. The tachometer-generator voltage would then be proportional to $\frac{d\,Rq}{dt}$ (from Eq. (5)) and the angular velocity of the tachometer-generator rotor would also be proportional to $\frac{d\,Rq}{dt}$. The angular position of a rotating shaft is the time integral of its velocity; therefore, the angular position of the tachometer-generator shaft would be proportional to range, Rq. The error introduced because the amplifier gain is finite is reduced by making the gain high, and the accuracy of computation is further improved by using "lag" compensation.

Figure 5 is a block diagram of the bearing computing section. The bearing servo uses the sine windings of the resolvers and operates in the same fashion as the range servo to generate a velocity proportional to $Rq\frac{d\,Bq}{dt}$. This velocity must be divided by range

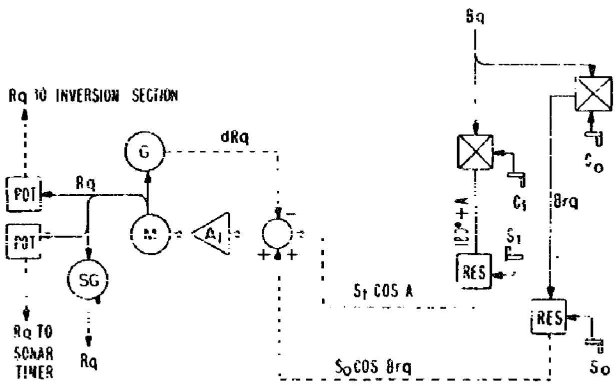

Fig. 4 - Range computer section of relative motion computer

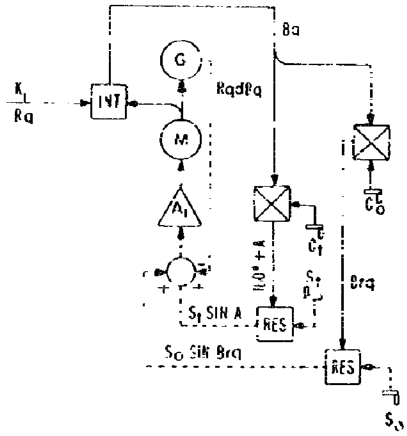

Fig. 5 - Bearing computer section of relative motion computer

to give the desired velocity, $\frac{d\,Bq}{dt}$, and the division is done by use of a ball-disc integrator. A ball-disc integrator is a mechanical device which permits a continuous and precise change of gear ratio. For a given integrator-input-shaft velocity, manipulation of the control shaft will cause the output velocity to decrease from a maximum value to zero and then increase in the reverse direction to the same maximum value. The linear position of the control shaft is accurately proportional to the output speed and is thus inversely proportional to the gear ratio. To divide the velocity, $Rq \frac{d\,Bq}{dt}$, by range, Rq, the integrator control shaft is moved to a position proportional to $1/Rq$ and the velocity, $Rq \frac{d\,Bq}{dt}$, is made the input to the integrator. The output speed will be proportional to the position of the control shaft and the input speed; therefore, the output speed will be proportional to the product $(1/Rq)\ (Rq \frac{d\,Bq}{dt})$, which is rate of change of bearing, $\frac{d\,Bq}{dt}$. The angular position of the output shaft is the time integral of the velocity, and is thus bearing, Bq.

Figure 6 is a diagram of the range inversion section. This section uses a high-gain amplifier with feedback proportional to range to develop an electrical signal proportional to inverse range. This signal is applied to a servo, which positions a resolver shaft to make the resolver output equal to the inverse range signal. A sine mechanism is used to convert the resolver shaft angle to a linear position proportional to inverse range. This linear motion is applied as the input to the control shaft of the integrator.

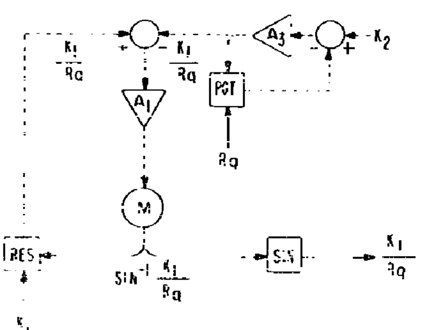

Fig. 6 - Range inversion computer of relative motion computer

The remaining servo in the Relative Motion Computer is used to repeat bearing, Bq, to facilitate mechanical arrangement of components.

Sonar Simulator

The Sonar Simulator, Fig. 7, alters the range and bearing signals from the Relative Motion Computer to incorporate the time lags and intermittent data features inherent in any sonar equipment, and in the SQS-4 in particular. The SQS-4 has delays not found in most sonars to aid the operator and in processing the data. The sequence of events in the SQS-4 is as shown in Fig. 8. The transmitter is keyed and the sonic pulse

is radiated omnidirectionally. Immediately following transmission, the equipment is set to receive; and, when the echo is received, it is displayed on a PPI oscilloscope. On the basis of hand-set range, the SQS-4 computes a time of echo and generates a sweep voltage for that time plus a delay time in order to assure that the true echo is shown even with the target fully evasive. At the end of this delay time, a cursor is presented for the operator to match to the echo position. The time of cursor presentation is referred to as dwell time. During dwell time all aided tracking information is interrupted and the sonar is cut off from the Attack Director, to permit easier and more accurate cursor matching. Aided tracking signals are restored at the end of dwell time, and, once the servos have synchronized, the sonar supplies the corrected range and bearing information to the Attack Director.

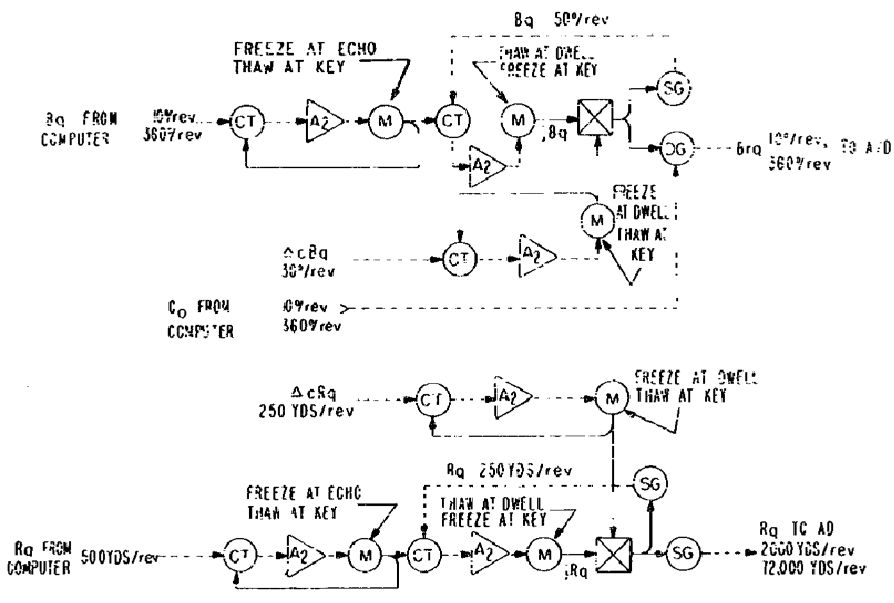

Fig. 7 - Sonar simulator

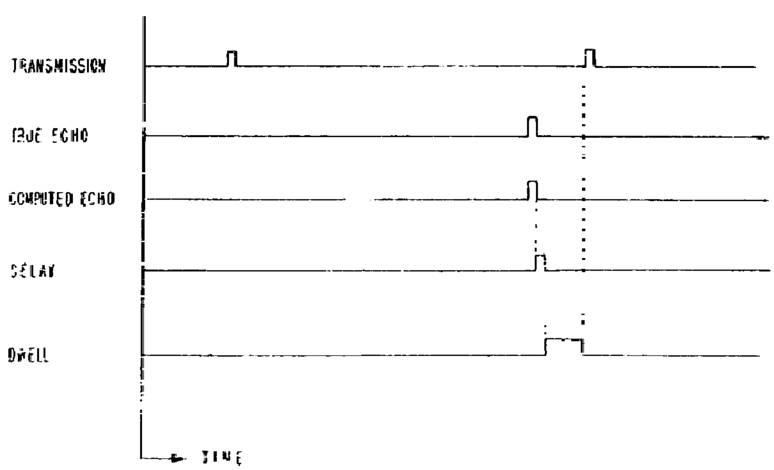

Fig. 8 - Time relationships in the SQS-4 sonar

A sonar timer is used to generate the delay between key and echo of the sonar signal, the constant delay of 400 or 250 milliseconds after echo, the 0.4 to 2.5 seconds dwell time, and the servo synchronizing time. During dwell time, operator corrections are added to the rate aided tracking information; while the Attack Director is held in Position Keeping, and the servos transmitting aided tracking information are frozen. At the end of dwell time, the aided track servos are released, but the Attack Director must be held in Position Keeping until these servos have synchronized to the sum of operator correction and accumulated aided tracking information in order to avoid giving the Attack Director false rates. The delay to permit the servos to synchronize is referred to as synchronizing or sync time. Controls are provided to set range scale and dwell time; a switch is provided to hold all servos operative and the Attack Director in On Target; and a switch is provided to remove the fixed delay of 400 or 250 milliseconds after echo.

The servos, Fig. 7, receiving range and bearing from the Relative Motion Computer, freeze these quantities at the time of echo. A period of 400 or 250 milliseconds later (depending on range), dwell time is initiated; the aided track (Δquantity) servos are frozen, the Attack Director is placed in Position Keeping, and the j-order servos are released to insert corrections. At the end of dwell time, the range and bearing servos and the aided track servos are energized; the j-order servos are frozen and the Attack Director is placed in On Target after the aided track servos are synchronized.

The mechanical differentials add the Δ quantities to the j-order corrections to generate the range and bearing signals fed to the Attack Director. The Attack Director must receive relative bearing as an input; therefore, own ship's course, C_o , is subtracted from generated true bearing in differential synchro generators to provide the Attack Director with relative bearing, Brq.

SAMPLES OF OPERATING PROCEDURE

Place Attack Director in Standby, and turn on Bias Switch on Simulator Power Supply. After blue indicator lights, turn on B+ Power Switch, and place Attack Director in Automatic, On, and Time Motor On. System is now ready for operation.

Normal procedure for selecting input information would be to select a minimum range, Rqm, and determine courses, speeds, and initial range on that basis. For parallel courses:

$$A = Brq \tag{7}$$

$$Rqm = Rq \sin A = Rq \sin Brq. \tag{8}$$

For nonparallel courses:

$$Rqm = Rq \cos |Brqm - Brq| \tag{9}$$

$$Brqm = \tan^{-1}\left[\frac{\frac{S_o}{S_t} + \cos (A - Brq)}{\sin (A - Brq)}\right]. \tag{10}$$

Equations (9) and (10) are solved in graphical form in Fig. 9.

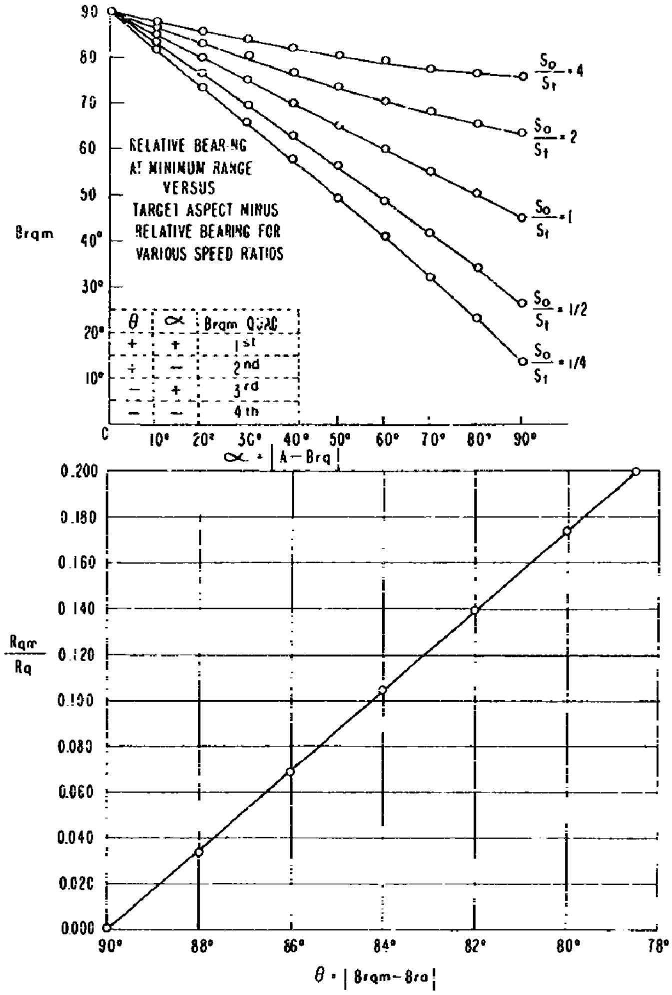

Fig. 9 -- Ratio of minimum range to range versus Brqm minus relative bearing

Examples of two problems are given below.

<u>Example 1</u>

Initial settings extant might be

Rq = 4000 yards

Bq = 027°

C_t = 030 °

C_o = 175 °

S_t = S_o = 0

Sonar Range Scale = 5000 yards

Sonar Dwell Time = position 2

Test Switch 1: ON (all servos on)

Test Switch 2: OFF (fixed delay in).

Since the Attack Director will accept information from 6000 yards in, computer range should be set to 6000 yards and range and bearing repeating servos should be checked for synchronism. If synchronism does not exist, turn off B+ Power on Simulator Power Supply and adjust the servos to agree. Turn B+ Power on.

Select a minimum range for parallel courses, for example: 200 yards. (Note: Minimum range should be in excess of 100 yards.) Determine initial aspect:

$$A_i = \sin^{-1}\frac{200}{6000} = 1.9° = Brq_i.$$

Determine C_t and C_o:

$$C_t = 180 + Bq - A_i$$

$$= 180 + 27 - 1.9 = 205.1°;$$

$$C_o = Bq - Brq_i$$

$$= 27 - 1.9 = 025.1°.$$

Make the initial settings:

$Rq = 6000$ yards

$C_t = 205.1°$

$C_o = 025.1°$

Sonar Range Scale: 10K yards

Sonar Dwell Time: Position 2.

Select speeds, for example, $S_o = S_t =$ 15 knots, and set these in; turn sonar test switch 1 to OFF. Problem is now generating. (Note: the j-order range servo may lose synchronism when computer S_t minus Attack Director S_t is in excess of 15 knots, Attack Director C_t is not approximately computer C_t, range in excess of 4000 yards, and dwell time in excess of 0.4 second (Position 1).)

Example 2

For the same initial conditions and the same Rq, select the angle $(A - Brq)$ and a speed ratio S_o/S_t. From Fig. 9 determine Brqm.

Let

$$A - Brq = 30$$

$$\frac{S_o}{S_t} = 2.$$

Therefore,

$$Brqm = 80.0°$$

$$\frac{Rqm}{Rq} = 0.0333.$$

Thus,

$$Brqm - Brq = 88.1^\circ$$
$$Brq_i = -0.1^\circ$$
$$A_i = 21.9^\circ.$$

The initial settings would then be

$$Rq = 6000 \text{ yards}$$
$$Bq = 27^0$$
$$C_o = 35.1^0$$
$$C_t = 185.1^0$$
$$\frac{S_o}{S_t} = 2 \text{ or } S_o = 30 \text{ knots}, S_t = 15 \text{ knots}.$$

The sonar timer range scale should be switched at the appropriate ranges and dwell time should be changed to Position 1 as soon as the Attack Director has a nearly correct solution as indicated by a small j-order correction.

The sonar timer test switch 2 may be turned ON to determine effect of eliminating the constant time delay after echo.

DESCRIPTION OF COMPONENTS

Servoamplifier A1

This amplifier, Fig. 10, adds a maximum of four signals in the summing amplifier stage, phases the resultant to be in quadrature relationship with the servomotor fixed field, and then amplifies the signal to a maximum level of approximately 12 watts to be applied to the servomotor control field. Jacks are provided for the inputs, for connection to a lag compensating preamplifier, for output to the servomotor, and for metering.

The summing amplifier [1] is a 6AU6 with 100% feedback to increase the input impedance for the purpose of elimination of input interaction. The output signal should be equal to an input signal applied to any one of the Input jacks or the Damping jack (with Damping control set for full gain), but with 180° phase shift.

The phasing amplifier uses a 6C4 to inject the signal into a phase shift circuit [2] made up of a transformer, a capacitor, and a potentiometer. The circuit will provide about 135° of phase shift with slight voltage gain, and thus permits accurate phasing of the servomotor control field voltage.

The power amplifier is a version of the "General Radio Signal-Ended Push-Pull" [3] amplifier designed to match the impedance of a Diehl FPE 25-11 servomotor. The 6AU6 and first half of the 12AU7 provide voltage gain; the second half of the 12AU7 is the driver and the 6Y6's make up the power stage. The two screwdriver-adjust potentiometers are used to set operating conditions for the 6Y6's. A 100-ma meter is connected to the metering jack on the chassis near the 6Y6's and a voltmeter is connected between chassis ground

[1] Seely, S., "Electron-Tube Circuits," New York:McGraw-Hill, 1950, p. 1948

[2] Chance, B., et al., eds., "Waveforms" (MIT Radiation Lab. Series No. 19),New York: McGraw-Hill, 1949, p. 136

[3] "General Radio Experimenter," October 1951

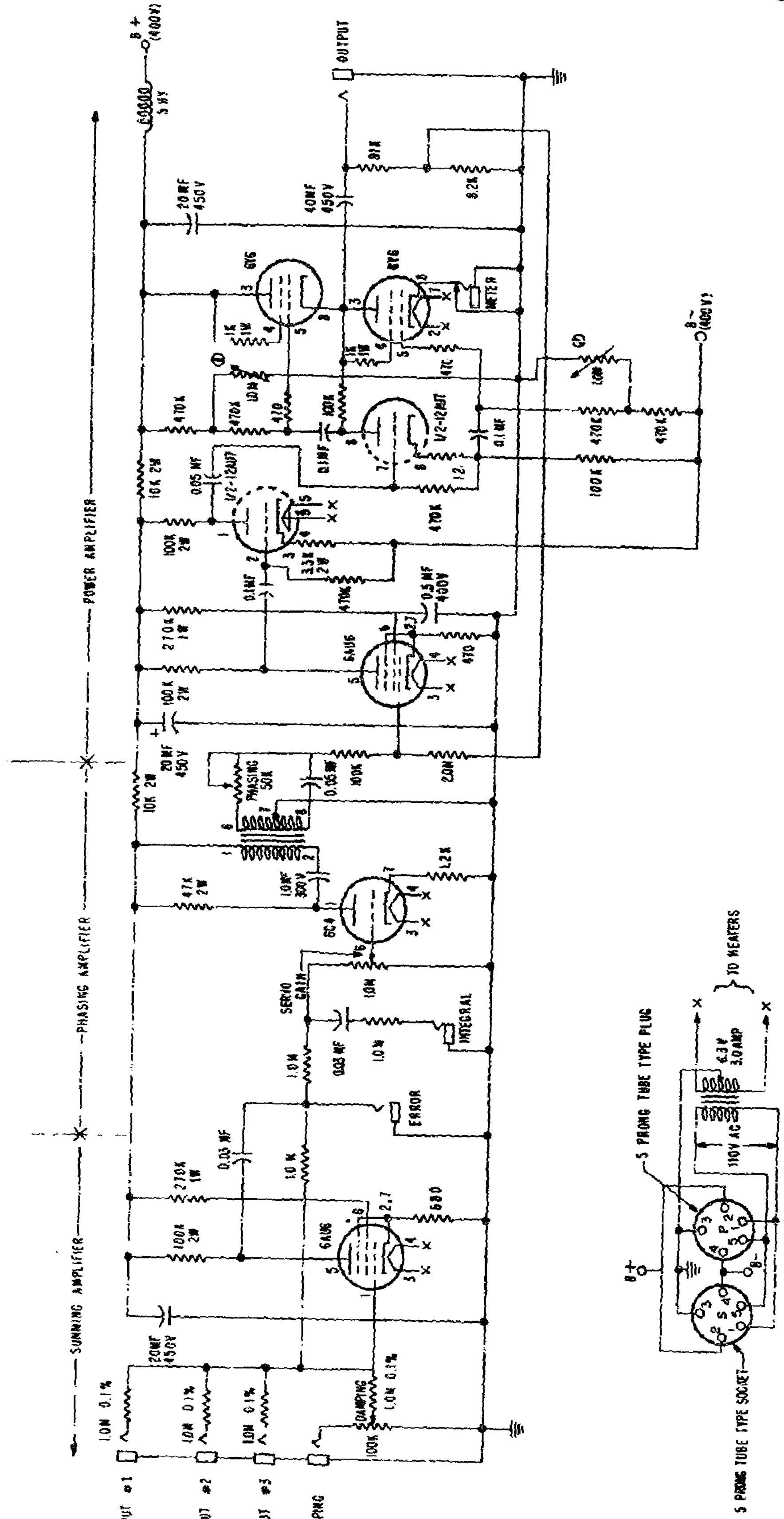

Fig. 10 - Servoamplifier, Type A1

and the blue pin jack. The two potentiometers are adjusted to give a voltage of 200 volts and a current of 40 milliamperes. If "motorboating" develops, the simplest cure would be to reduce the amount of voltage feedback around the power amplifier by reducing the value of the 8.2K resistor which is in series with a 91K resistor connected to the output.

The gain adjustment is set to that value of gain just below servo oscillation.

Servoamplifier A2

This amplifier, Fig. 11, is designed for use with a two-speed synchro-servo using tachometer-generator damping.

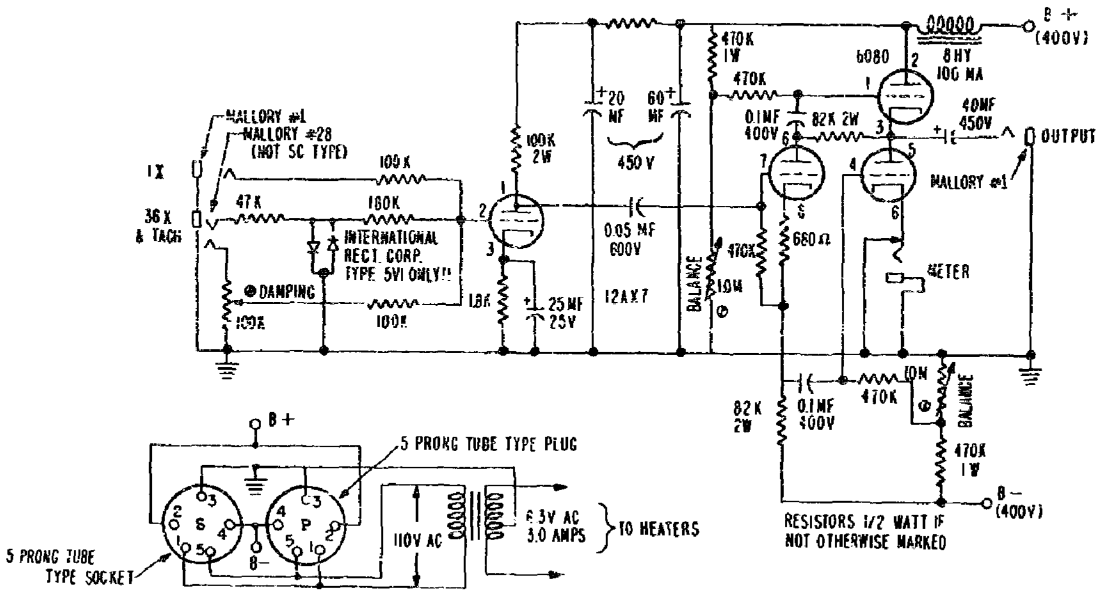

Fig. 11 - Servoamplifier, Type A2

The reason for using a two-speed synchro system is to obtain additional accuracy over a one-speed system. For example, a one-speed (1X) system could be used to repeat bearing with 360° of bearing equal to one revolution of the synchro shaft. The accuracy to be expected in this system using size-1 synchros would be approximately ±30 minutes. If an additional synchro is added, geared 10° of bearing per revolution of the synchro shaft (36X), the accuracy would be approximately ±1 minute. However, some method of selection must be provided to use the 1X synchro for large errors and the 36X for small errors.

The selection, or crossover, network used in this amplifier is made up of the series input resistors and the two selenium diodes. The diodes serve as ac limiters to limit the 36X synchro signal to a value which permits the 1X synchro to assume control for errors larger than 3°.

Tachometer-generator voltage is used for damping and is controlled by the screwdriver adjust potentiometer marked Damping. Damping is adjusted as necessary to keep servo from oscillating.

The 12AX7 and the 6080 tubes operate in the same fashion as the 12AU7 and 6Y6 tubes in amplifier, A1. The operating conditions for the 6080 are set by connecting a 100-ma meter to the metering jack and a voltmeter between ground and pins 3 and 5 of the 6080. The balance potentiometers are used to set current to 40 milliamperes and the voltage to 200 volts.

Servo Integrator

Figure 12 is a schematic of the active network used to provide lag compensation of the range and bearing servos. The operation of this network is covered fully in Reference 4. Briefly, the network acts as a pseudo integrator to reduce steady-state errors to a fraction of their normal value.

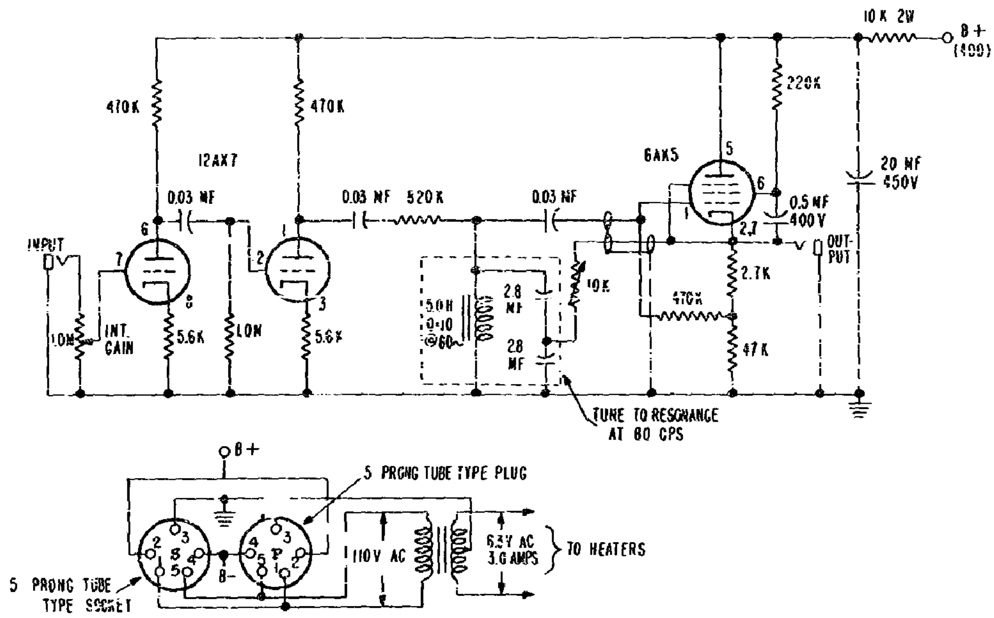

Fig. 12 - Servo integrator

The input of the compensator is connected to the Error jack on A1, and the output is connected to the Integral jack.

The Time Constant control should be set to about one-half and gain then increased to a point just below servo oscillation.

Range Inversion Amplifier A3

Figure 13 shows the schematic for the inversion amplifier. This amplifier is simply a high-gain dc amplifier which has inverse feedback varied by range. The usual feedback amplifier equation is thus

$$K = \frac{u}{1 - uRq}.$$

Consequently, for uRq large, the amplifier gain is $1/Rq$.

[4] Looney, C. H., "An Equalizing Network for Carrier-Type Feedback Control Systems," Proc. IRE. 43 (No. 1):22-22, 1955

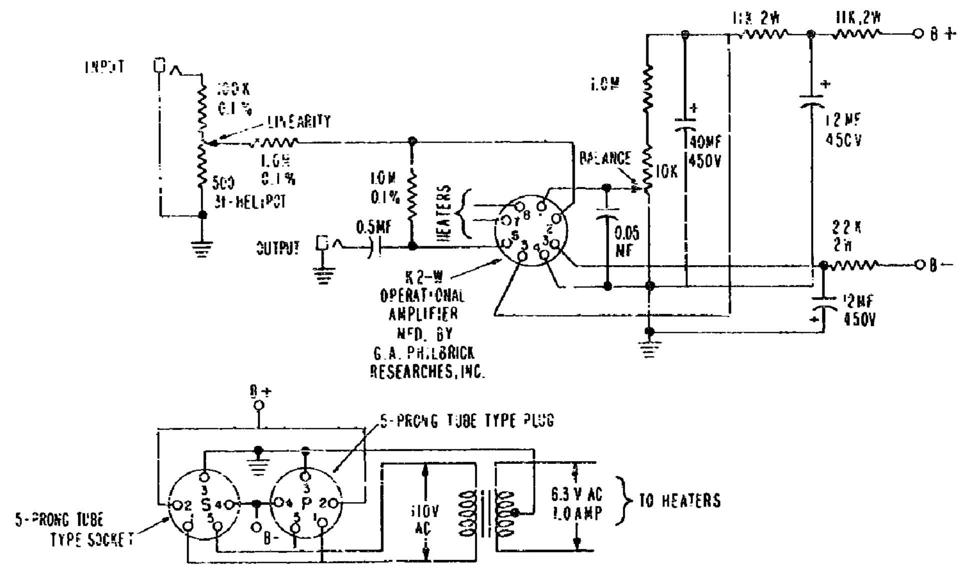

Fig. 13 - Inversion amplifier, Type A3

The only controls are balance and input voltage magnitude which determines linearity of the Relative Motion Computer. Balance control is set by reducing computer range to 150 yards and adjusting balance potentiometer for minimum 120-cps component in the error voltage of the main servoamplifier for this servo. Linearity is set to that point giving most accurate computation from 6000 yards in to a minimum range of approximately 200 yards. The best setting will, of course, be a compromise, but linearity should be well within ±25 yards of a straight line course.

Sonar Timer

The Sonar Timer, Fig. 14, generates pulses at the time of keying the mock sonar transmitter, at the time the echo would be detected, at the end of the fixed delay T_c, and at the end of dwell time, T_d. The timer also provides a delay (during synchronization of the Δ-quantity servos) before returning the Attack Director to On Target.

The time base is established by the circuit including V1, V15, and V16. An ac voltage proportional to the reciprocal of the range scale established by the range switch is rectified by V15 and V16 and then charges the 2.0-MF capacitor connected to the grids of V1. The tube V1 is a cathode follower used in a "bootstrap" circuit to linearize the charge curve of the RC network made up of the precision 1.0-M resistor and the 2.0-MF capacitor. The voltage from the cathode follower, V1, is thus a linearly rising voltage having a slope proportional to the range scale selected.

This rising voltage could be termed a sweep voltage, and, in fact, is used as the PPI sweep voltage in the SQS-4. The time of echo is determined by subtracting a dc voltage proportional to range from the sweep voltage and triggering a multivibrator at the time this difference voltage goes through zero. The dc voltage proportional to range is developed from the circuit including tubes V2, V3, and V4, and the pulse at echo is formed by tube V5.

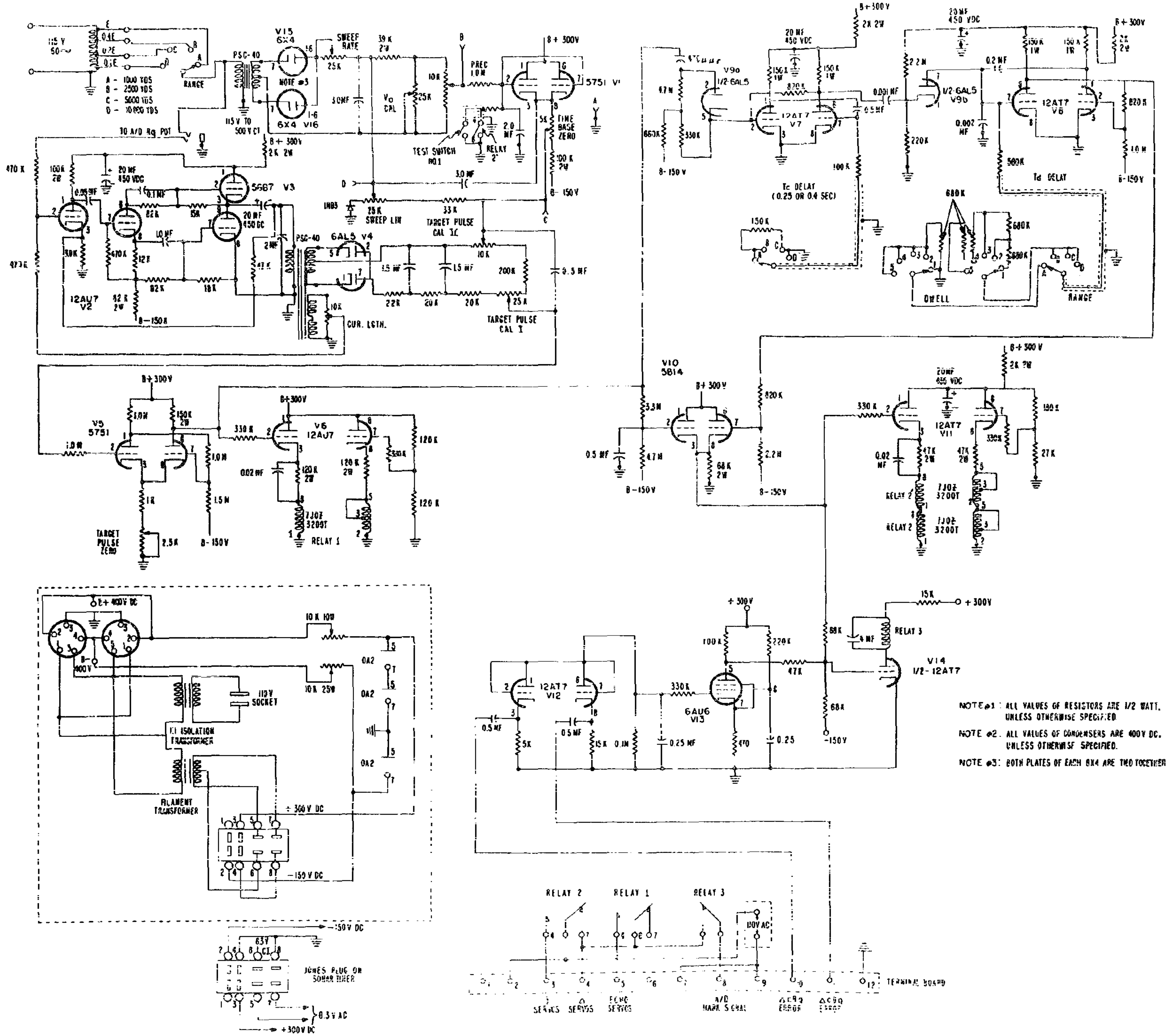

Fig. 14 - Sonar timer

Tube V6 operates Relay 1 at echo time. A time delay of 400 or 250 milliseconds (depending on range) occurs in the SQS-4 after computed echo to avoid the possibility of losing the actual echo. This delay is generated by V7 and V9a. Dwell time is established by the multivibrator utilizing tubes V8 and V9b. The dwell time is varied from 0.4 to 2.5 seconds by the Dwell switch. V11 operates Relays 2 and 2' during dwell time. V10 supplies a pulse to V11 during dwell time, or, if the dwell time multivibrator is not triggered, V10 raises the grid of V11 to operate the relays when the sweep voltage has progressed to a point well beyond full scale. Relay 2' shorts out the sweep capacitor to ready the circuit for the next cycle of operation.

Relay 1 is used to freeze the range and bearing servos to the range and bearing values at the time of echo. Relay 2 is used to freeze the Δ-quantity servos and to thaw the j-order servos during dwell time. The dwell time pulse is fed to tube V14 to operate Relay 3 which puts the Attack Director in Position Keeping. Error signals from the Δ-quantity servos are rectified by V12, amplified by V13, and applied to V14 to hold Relay 3 open until the servos are synchronized, thus keeping the Attack Director in Position Keeping during dwell time plus synchronizing time.

Circuit adjustments are made primarily to set the slope of the sweep voltage and the magnitude of the range voltage to calibrate key-to-echo times. SQS-4 adjustments are made on the basis of scope presentation, but, since the timer has no associated display, the adjustments are made in a different manner. With test switch 1 turned ON, range scale 1000, and range of 1000 yards, Time Base Zero is adjusted to make the voltage from jack C to jack A equal to zero, and Sweep Linearity is adjusted to make the voltage from jack D to jack A equal to zero. V_o Cal or V_c is adjusted to make the voltage from jack B to jack D equal to 156° volts corresponding to a sound velocity of 4800 ft/sec. Connect an oscilloscope Y amplifier between jack C and ground; turn X amplifier OFF; connect the Z input to pin 8 of Relay 1 socket, and connect a 1000-ohm resistor between the Z input and ground. Set range scale to 2500 and simulated range to 2500 yards with test switch 1 OFF. Adjust oscilloscope gain so that the deflection from the position of the C-R beam during dwell to the beam position when brightened is five squares. Set simulated range to 500 yards and adjust T. P. Zero to make the deflection from dwell position to brightened position one square. Return simulated range to 2500 yards and adjust T. P. Cal I or II to make the deflection five squares. Repeat until further adjustments are unnecessary. Check the time from key to echo (brightened C-R beam) for simulated range of 2500 yards and range scale of 2500. Adjust Sweep Rate to make the time equal to 3.06 seconds.

Power Supply

Figure 15 is a schematic of the power supply used by all the servoamplifiers and associated electronic instruments in the simulator and computer. Three-phase ac is transformed open delta and applied to a three-phase selenium rectifier which supplies +400 volts at 3.0 amperes maximum. Single-phase ac is used to develop a bias supply of -400 volts at 50 milliamperes. A dc relay is operated by the bias voltage to delay or interrupt application of B+ until bias voltage is present. Current and voltage metering jacks are provided for testing. A blue pilot light indicates presence of bias voltage and a red pilot light indicates B+.

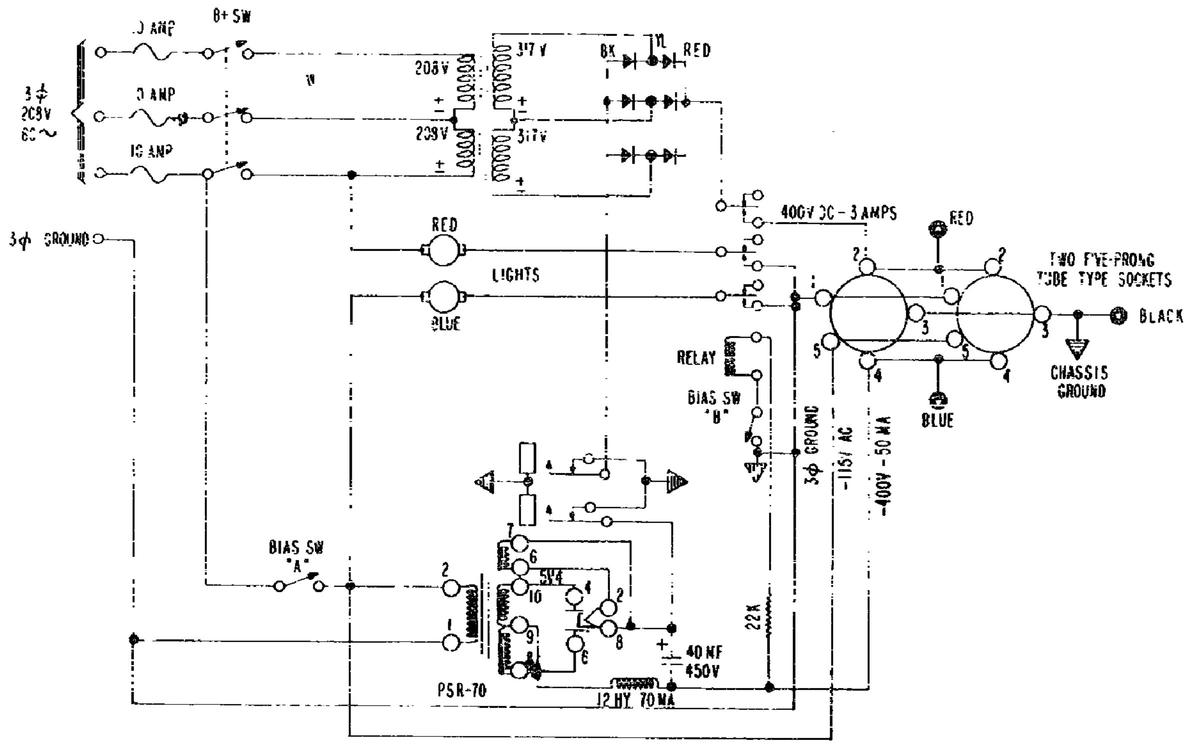

Fig. 15 - Three-phase power supply

SUMMARY

Tables 1 and 2 give data on two generated problems; the first with parallel courses and the second with nonparallel courses. It can be seen that deviation of the ships from the desired courses is ±16 yards, or less. This error corresponds to the error which would exist if a ship traveling at a speed of 15 knots were allowed a course deviation of $\pm 1.8^{\circ}$ for a period of one minute. The deviation from correct distance traveled is approximately ±25 yards corresponding to a speed error of approximately ±0.75 knot for a period of one minute. This accuracy has proven adequate for the intended purpose of the simulator and is probably more accurate than necessary for use as a trainer.

The Relative Motion Computer and the Sonar Simulator provide a means for evaluating performance of the Attack Director when receiving sonar data on a moving target and the simulation equipment has proven an excellent aid in maintaining the Attack Director in optimum condition. The equipment enabled an operator to discover abnormal operation of the Attack Director which was causing inaccurate problem solutions when fed sonar-type data while the standard test problems gave no indication of difficulty.

TABLE 1
Data on Parallel Courses

Time (sec)	C_o = 000	C_t = 180		S_o = 15 knots		S_t = 15 knots		
	Rq (yd)	Bq (deg)	Brq (deg)	Rq Sin Brq Rqx (yd)	Error (yd)	Rq Cos Brq Rqy (yd)	ΔRqy (yd)	Error (yd)
0	6000	002.0	002.0	209	0	6000		
15	5720	002.1	002.1	209	0	5720	280	
45	5200	002.2	002.2	200	-9	5200	520	-9
75	4680	002.4	002.4	196	-13	4680	520	-9
105	4160	002.8	002.8	203	-6	4160	520	-9
135	3640	003.1	003.1	197	-12	3640	520	-9
165	3120	003.7	003.7	201	-8	3110	530	+1
195	2580	004.5	004.5	202	-7	2570	540	+11
225	2060	005.7	005.7	205	-4	2050	520	-9
255	1540	007.6	007.6	204	-5	1530	520	-9
285	1030	011.6	011.6	207	-2	1010	520	-9
315	540	023.5	023.5	215	+6	495	515	-14
?	220	090.0	090.0	220	+11	0	495	
375	610	160.0	160.0	209	0	570	570	+3.5
405	1100	169.6	169.6	199	-10	1080	510	-19
435	1610	173.0	173.0	196	-13	1600	520	-9
465	2120	174.7	174.7	196	-13	2110	510	-19
495	2640	175.8	175.8	193	-16	2630	520	-9
525	3160	176.5	176.5	193	-16	3160	530	+1
555	3660	176.9	176.9	198	-11	3660	500	-29
585	4180	177.2	177.2	204	-5	4180	520	-9
615	4700	177.5	177.5	205	-4	4700	520	-9
645	5220	177.7	177.7	209	0	5220	520	-9
675	5740	177.9	177.9	210	+1	5740	520	-9
?	6000	178.0	178.0	209	0	6000	260	

TABLE 2
Data on Nonparallel Courses

Time (sec)	C_o = 186.1°		C_t = 336.1°		S_o = 18 knots		S_t = 9 knots		
	Rq (yd)	Bq (deg)	Brq (deg)	Brqm-Brq (deg)	Rq Cos|Brqm-Brq| Rqx (yd)	Error (yd)	Rq Sin|Brqm-Brq|Rqy (yd)	ΔRqy (yd)	Error (yd)
0	6000	178	-8.1	88.1	199	0	6000		
15	5760	178.1	-8.0	88.0	201	-2	5760	240	
45	5320	178.2	-7.9	87.9	195	-4	5320	440	-5
75	4870	178.4	-7.7	87.7	196	-3	4870	450	+5
105	4420	178.7	-7.4	87.4	200	+1	4420	450	+5
135	3980	179.0	-7.1	87.1	201	-2	3980	440	-5
165	3540	179.3	-6.8	86.8	198	-1	3540	440	-5
195	3090	179.8	-6.3	86.3	200	+1	3090	450	-5
225	2640	180.3	-5.8	85.8	193	-6	2630	460	+15
255	2200	181.2	-4.9	84.9	196	-3	2190	440	-5
285	1750	182.5	-3.6	83.6	195	-4	1740	450	+5
315	1320	184.7	-1.4	81.4	197	-2	1310	430	-15
345	870	189.4	+3.3	76.7	200	+1	850	460	+15
375	450	204.0	17.9	62.1	210	+11	400	450	+5
?	215	266.1	80.0	0	215	+16	0	400	
435	570	335.5	149.4	69.4	205	+6	530	530	+20
465	1000	345.0	158.9	78.9	193	-6	980	450	-5
495	1450	348.6	162.5	82.5	190	-9	1440	460	+15
525	1890	350.3	164.2	84.2	191	-8	1880	440	-5
555	2340	351.5	165.4	85.4	188	-11	2330	450	+5
585	2790	352.2	166.1	86.1	190	-9	2780	450	+5
615	3240	352.7	166.6	86.6	192	-7	3240	460	+15
645	3680	353.0	166.9	86.9	199	0	3680	440	-5
675	4120	353.3	167.2	87.2	201	+2	4120	440	-5
705	4570	353.6	167.5	87.5	199	0	4570	450	-5
735	5010	353.8	167.7	87.7	201	-2	5010	440	-5
765	5460	353.9	167.8	87.8	200	+1	5460	450	+5
?	6000	354.1	168.1	88.1	199	0	6000	540	-5

* * *

APPENDIX A
Mechanical Components

Figures A1 through A6 are gear diagrams of the shaft relationships in the mechanical components of the Sonar Tracking Simulator and are included to give a concept of the physical complexity of the equipment.

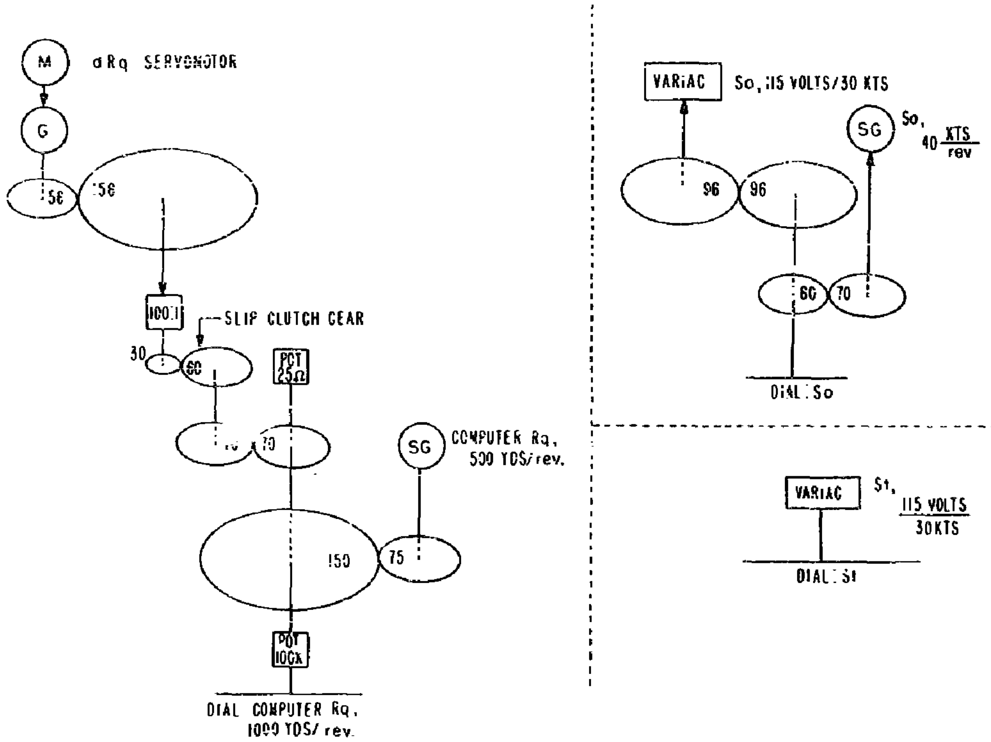

Fig. A1 - Range rate servo; speed sections

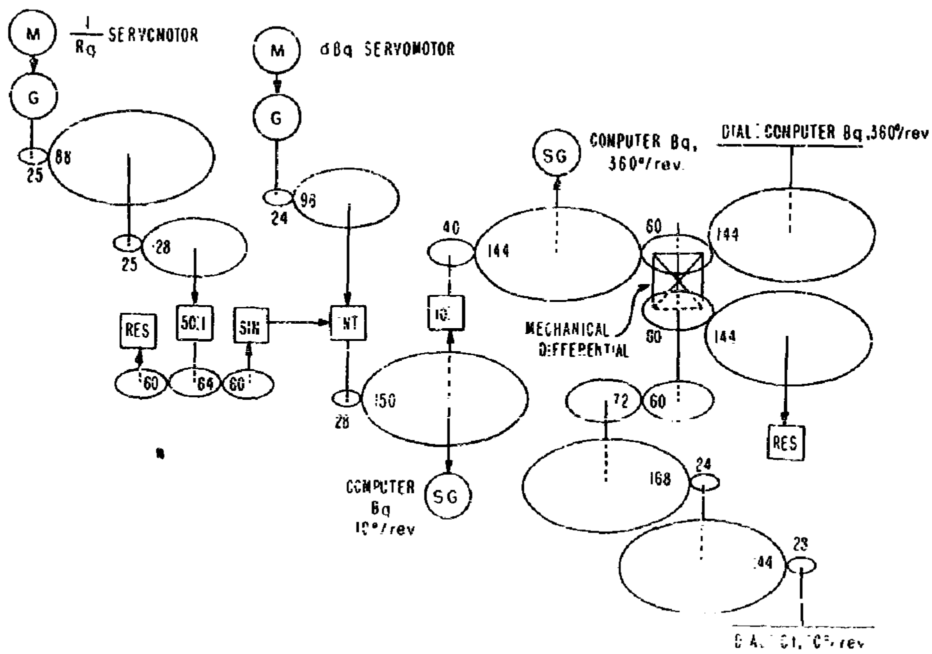

Fig. A2 - Range inversion and bearing-rate servos

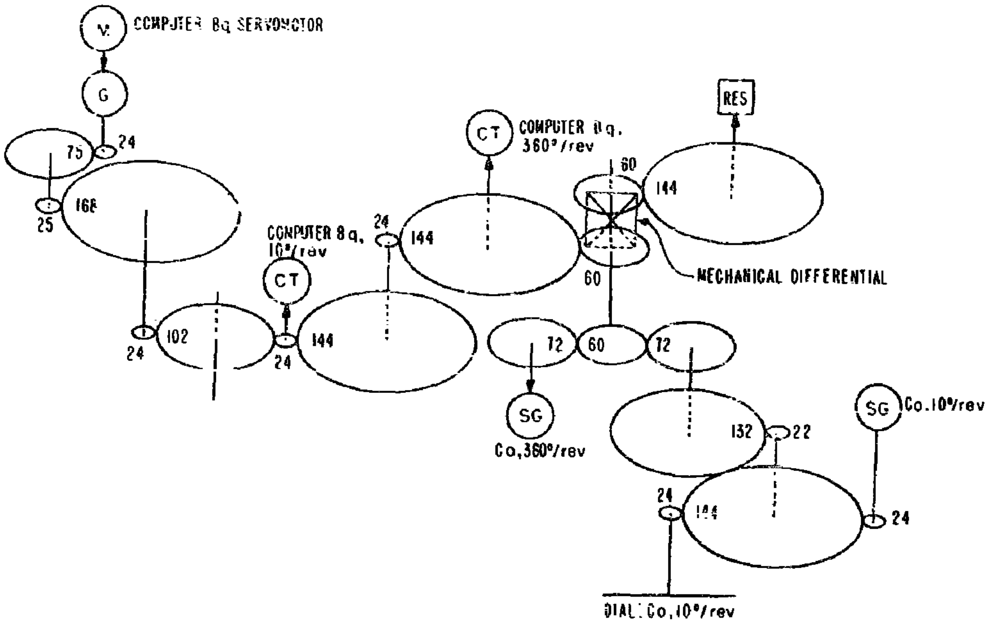

Fig. A3 - Bearing repeating servo

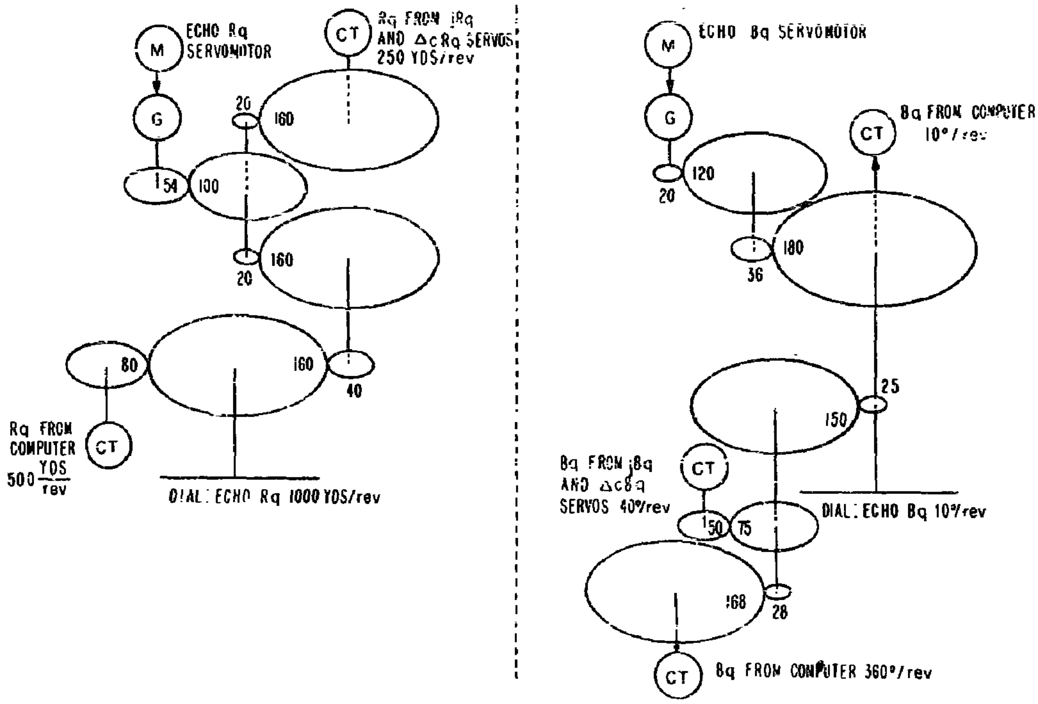

Fig. A4 - Echo servos

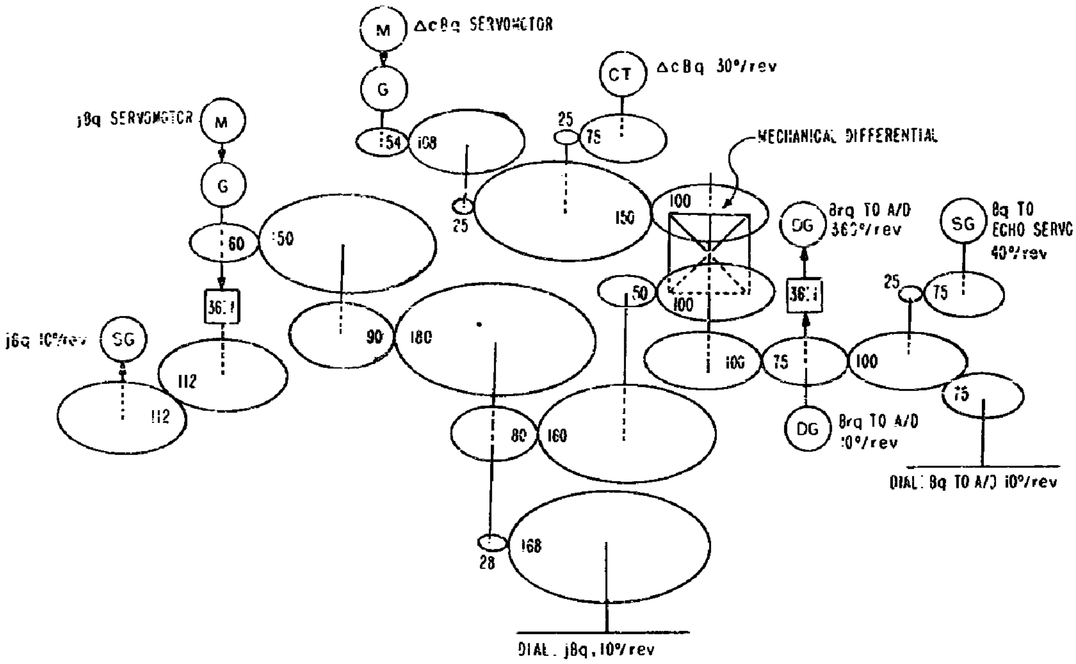

Fig. A5 - jBq and ΔcBq servos

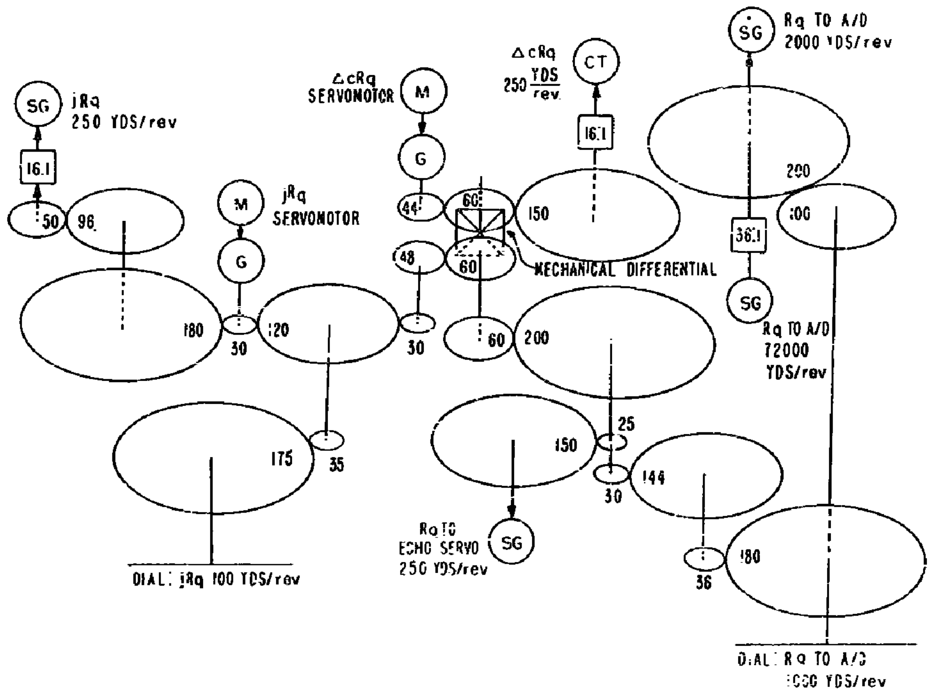

Fig. A6 - jRq and ΔcRq servos

* * *

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CONFIDENTIAL

Naval Research Laboratory. Report 4726 [CONF.] SIMULATION OF SONAR TRACKING [Confidential Title] by Chesley H. Looney, 25 pp. & figs., May 22, 1956.

Equipment has been developed which generates range and bearing data comparable to that obtained from maneuverable own ship and target ship. This continuous information is converted, through circuits simulating the information-handling circuits of the SQS-4 Sonar, to the intermittent data flow which exists between the SQS-4 Sonar and the Mark 5 Attack Director. This equipment has been connected to a Mark 5 Attack Director and has been used to simulate operation of a Mark 105 Fire Control System. [Confidential abstract]

CONFIDENTIAL

1. Sonar target simulators - Design
2. Sonar equipment - Simulation

I. Mark 5
II. Relative Motion Computer
III. SQS-4
IV. Looney, C. H.

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CONFIDENTIAL

UNITED STATES GOVERNMENT

memorandum

7103/113

DATE: 23 October 1996

FROM: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF. (a) FOR DECLASSIFICATION

TO: Code 1221.1

VIA: Code 7100

AD-099 264

REF: (a) NRL Confidential Report #4726 by C.H. Looney, May 22, 1956 (U)

1. Reference (a) is a report on an improved method for simulating the tracking of a submarine with an AN/SQS-4 sonar and an Attack Director, MK 5. This system includes the design and electronics of a relative motion computer and a sonar simulator.

2. The technology and equipment employed in this system have been superseded and are no longer relevant.

3. Based on the above, it is recommended that reference (a) be declassified with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
Acoustics Division

CONCUR:

10/25/96

EDWARD R. FRANCHI — Date
Superintendent
Acoustics Division

Completed
2-7-2000
J.W.